Resource Recovery from Wastewater

Partners for Pollution Prevention, Quarterly Meeting
Purdue University, West Lafayette, IN
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Municipal Wastewater

- Viewed as a burden
  - Not a money maker
  - Cost to treat
  - Paid for by users
    - Homeowners
    - Businesses
    - Industry
- Current goals: Protection of human health and the environment
  - DO
  - Nutrients
  - Aesthetics
  - Microbial pathogens

Wastewater Infrastructure: Status

- 2013 *Report Card for America's Infrastructure*: Wastewater Grade = D
- Large fraction of receiving waters unfit for fish, wildlife, recreation, water supply
- Aging pipes
- Nutrient control
- CSOs

From: http://eblakewi.com/what-s-new/why-your-titles-should-be-no-longer-than-this

From: http://www.purdueexponent.org/city/article_1efc56e4-96de-5a64-9c9b-6e06692b5ada.html

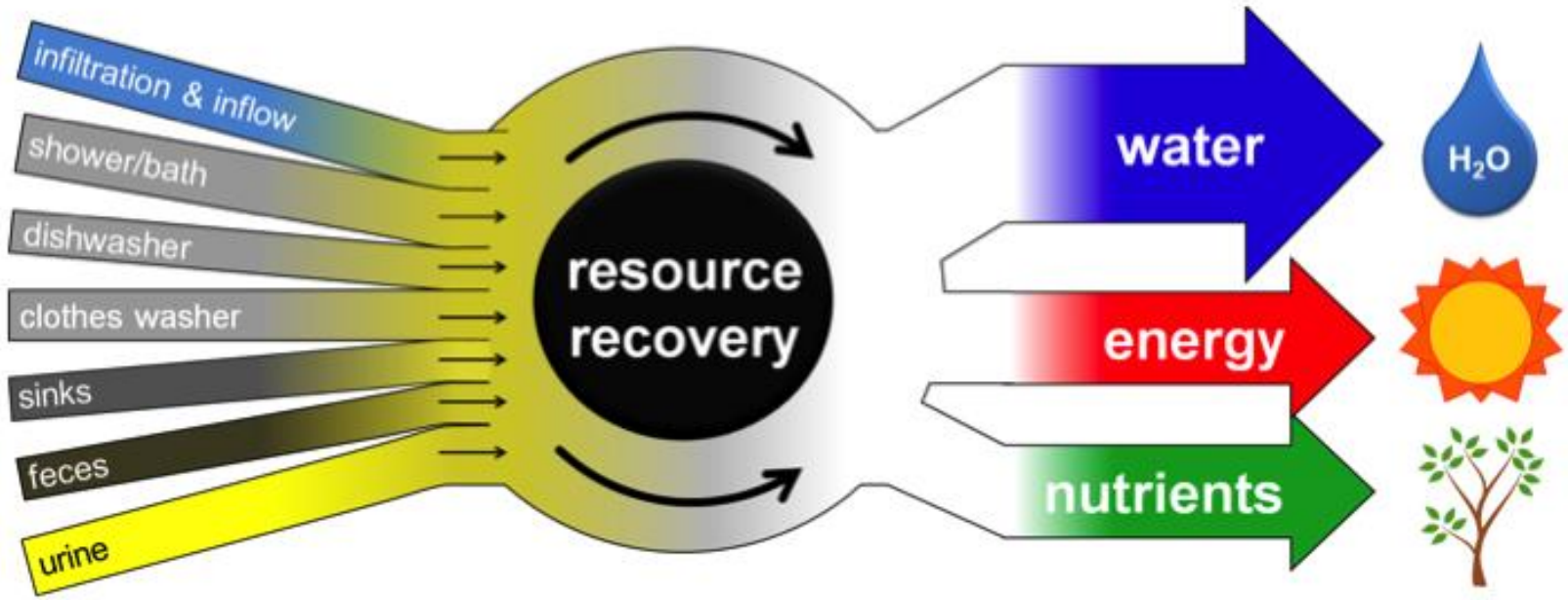
Contemporary Wastewater Treatment

- Roughly 15,000 systems in the U.S.
- Centralized
- Municipally owned and operated
- Goals: Protection of human health and the environment
  - BOD
  - Solids
  - Nutrients (N and P)
  - Microbial pathogens
  - Sludge management

West Lafayette, IN

Wingate, IN

Opportunities for Resource Recovery from Municipal Wastewater



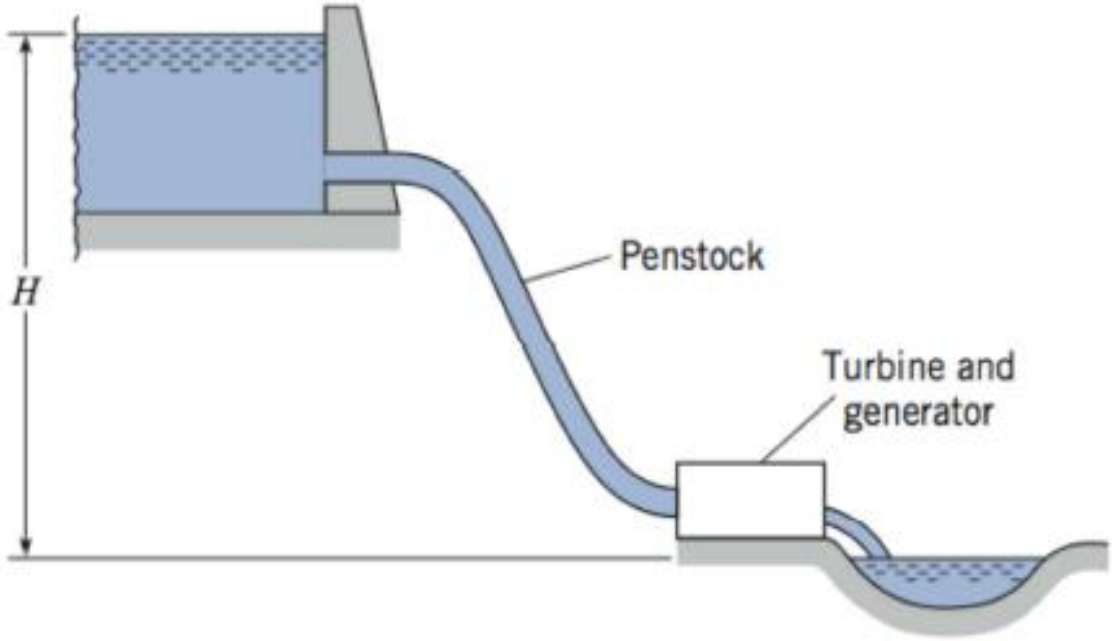
From: http://urbanfabrick.com/future-of-designing-with-water/

Can be implemented in a manner to meet or exceed current protection of human health and the environment

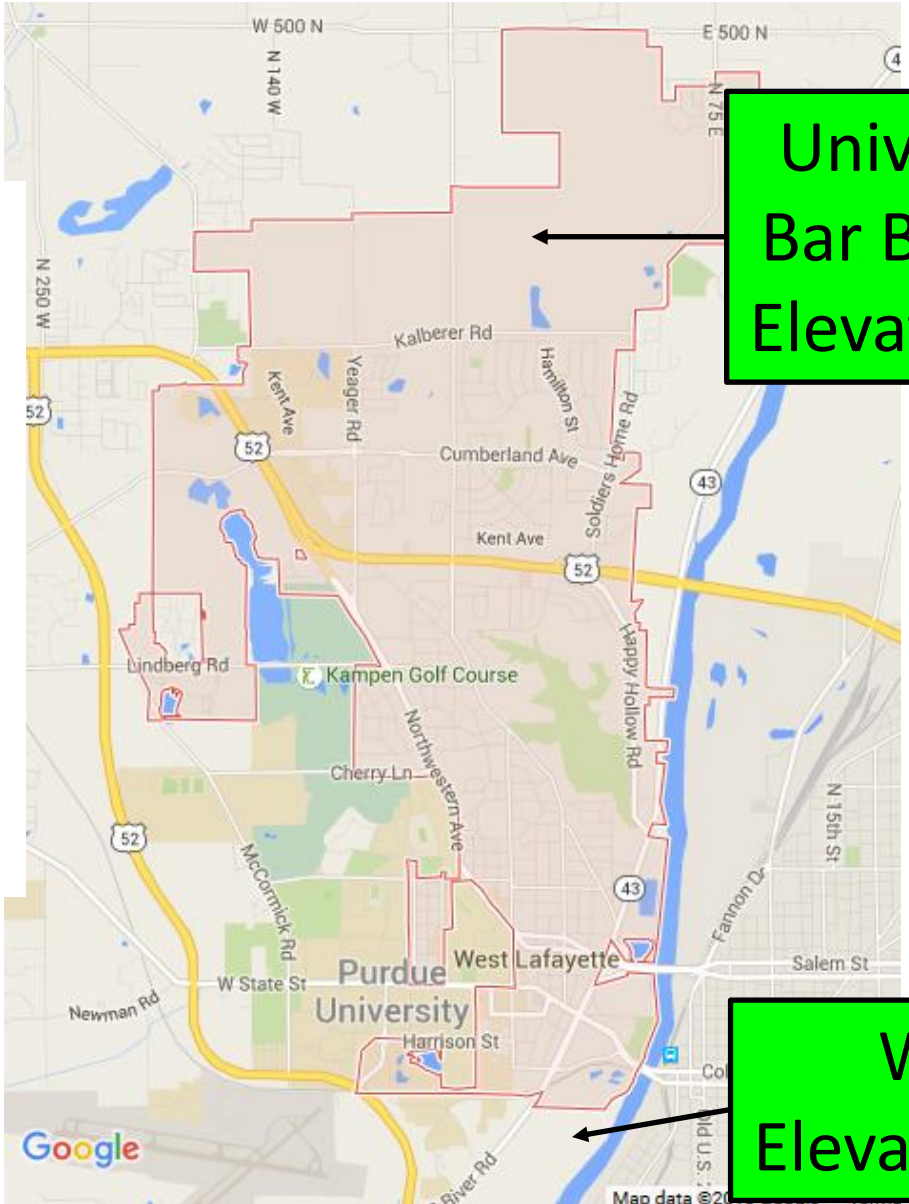
Energy Recovery: Chemical

- WLWWTP
  - CH_4 capture
  - Feed augmentation
  - Microturbines

Recovery of Potential Energy: West Lafayette



$$P = \rho \cdot g \cdot Q \cdot \Delta H$$



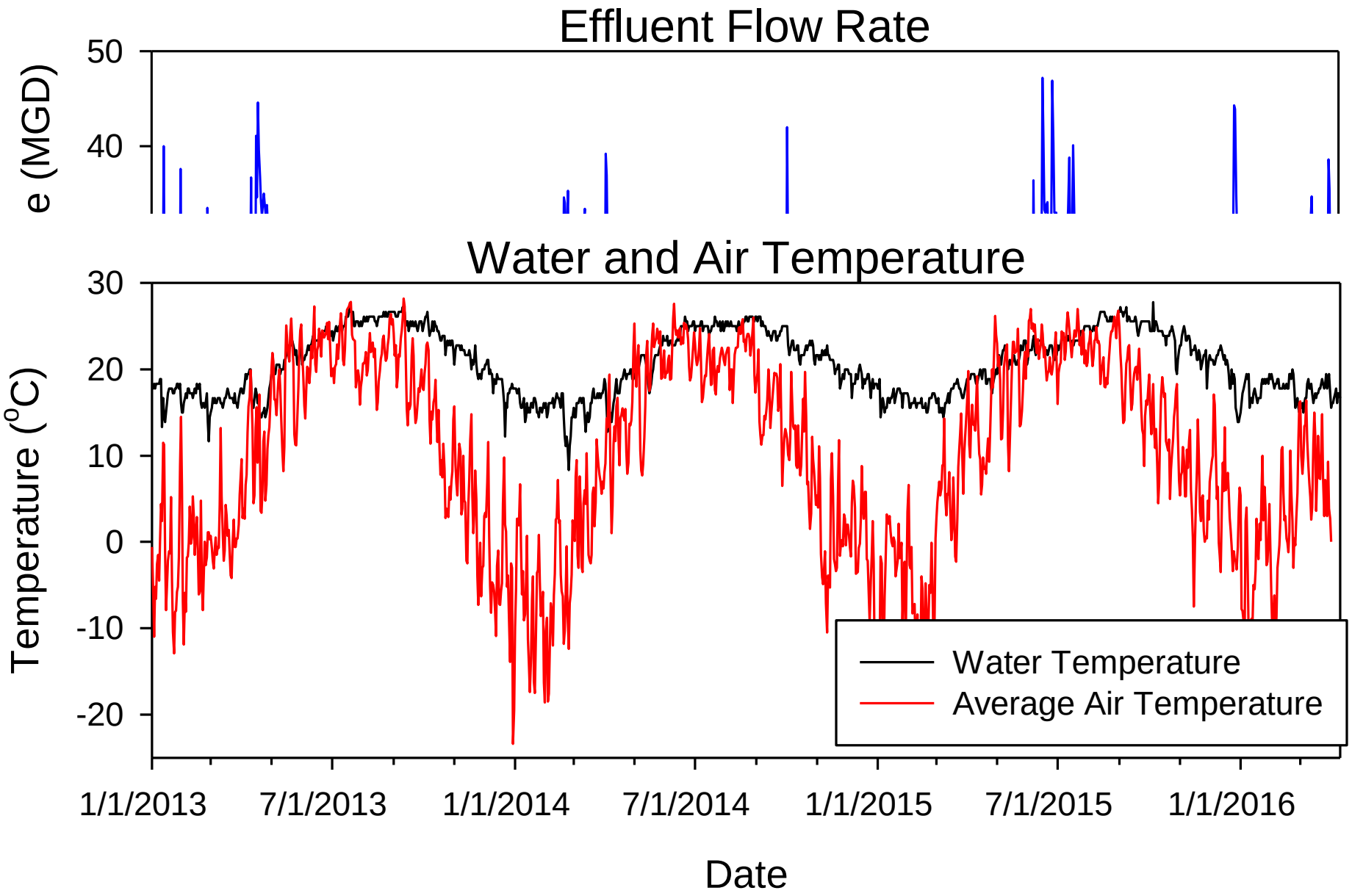
University Farm, Bar Berry Heights Elevation ≈ 720 ft.

WLWWTP Elevation ≈ 530 ft.

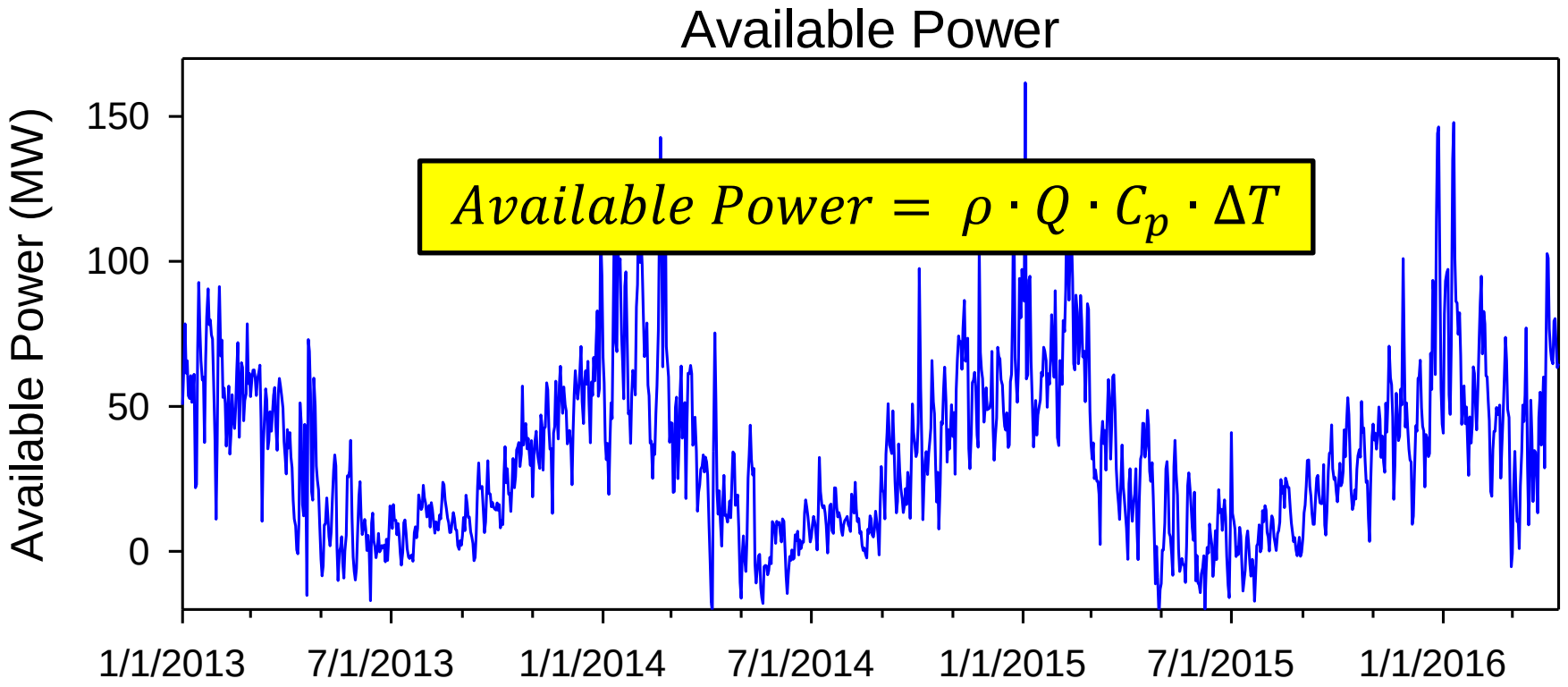
Recovery of Potential Energy: West Lafayette

- $\Delta H = 190\ ft$
- Assume $Q = 4.5\ MGD$
- Assume 50% recovery
- P = 56 kW
- WLWWTP average power usage = 514 kW
- ~11% power recovery

Energy Recovery: Thermal



Energy Recovery: Thermal



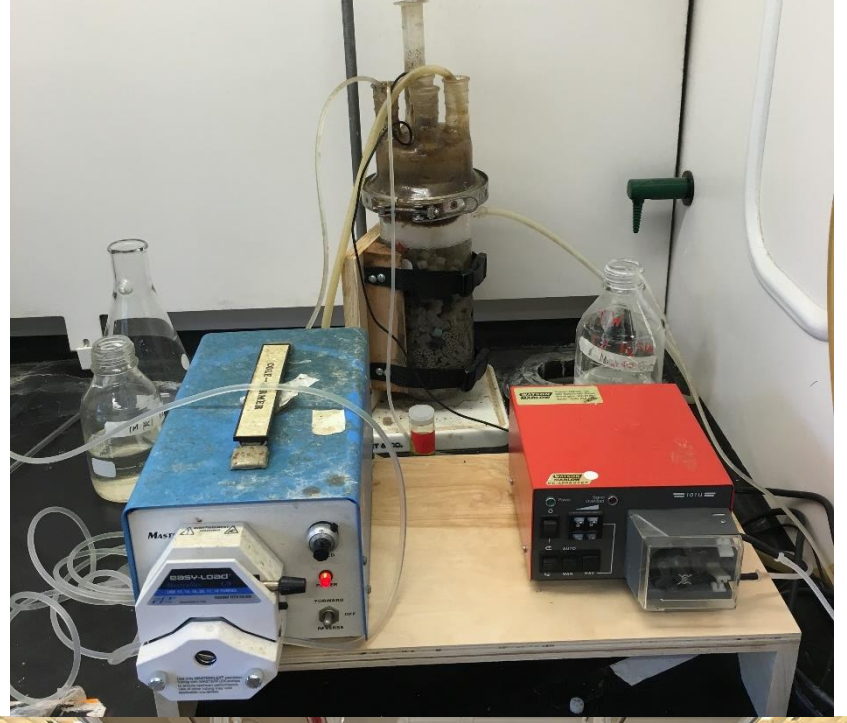
- Avg. available power ≈ 33 MW = 1.1 x 10^8 BTU/hr
- 2000 ft^2 home in Indiana: 60 x 10^6 BTU to heat in winter
- Enough energy to heat ~ 8000 homes for 6 months/year
- Lafayette WWTP power requirement ≈ 0.9 MW (avg.)

Nutrient Recovery

- Urine composition
  - Little or no microbial contamination
  - Large fraction of N, P, K
- Urine management
  - Dilution in potable water
  - Discharge to POTW
  - Contribute to eutrophication, hypoxia, HABs
  - Transformation or separation

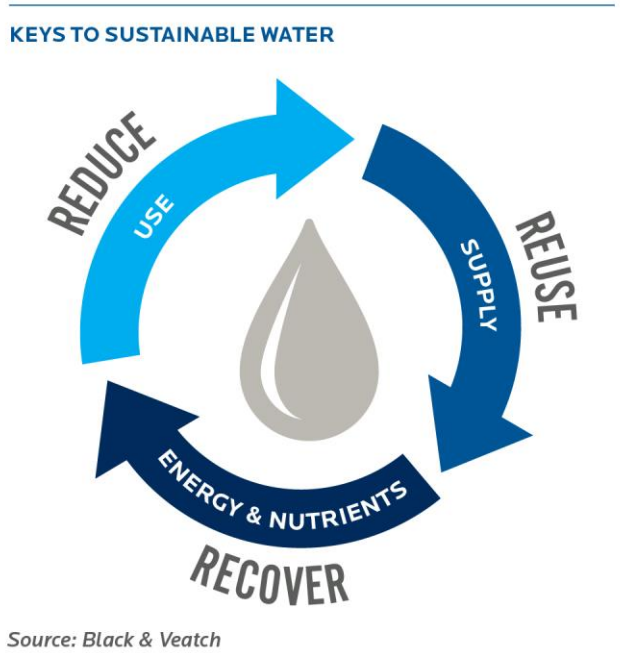
Nutrient Recovery from Human Urine

- Biochemical conversion of reduced-N to NO_3^-
  - Stable form of N
  - Non-volatile (odor, control of losses)
  - Used by plants
- Dewatering
- Product = natural fertilizer
- Nutrient recovery in Lyles Hall of Civil Engineering
- Nutrient recovery at Purdue?, Elsewhere?



Water Recovery (Reuse)

- Water comprises >99% of wastewater, by mass
- Opportunities, needs for water reuse
  - Requires regulatory framework
  - Stricter standards on treatment
- CA *Title 22*
  - Recycled water used for the surface irrigation of: Food crops, Parks and playgrounds, School yards, Residential landscaping, golf courses



Source: Black & Veatch

Rain Water Recovery: Rain Barrels

- Example calculation: West Lafayette
- ~5000 homes
- Rooftop area ~1000 ft^2/home
- Average annual rainfall ~38”
- Assume 50% collection by rain barrels
- Yield ≈ 60 x 10^6 gallons/year
  - Roughly equivalent to 1 week of flow from the WLWWTP
  - 2015 WLWWTP data
    - 35 CSO events
    - 6.4 x 10^6 gallons

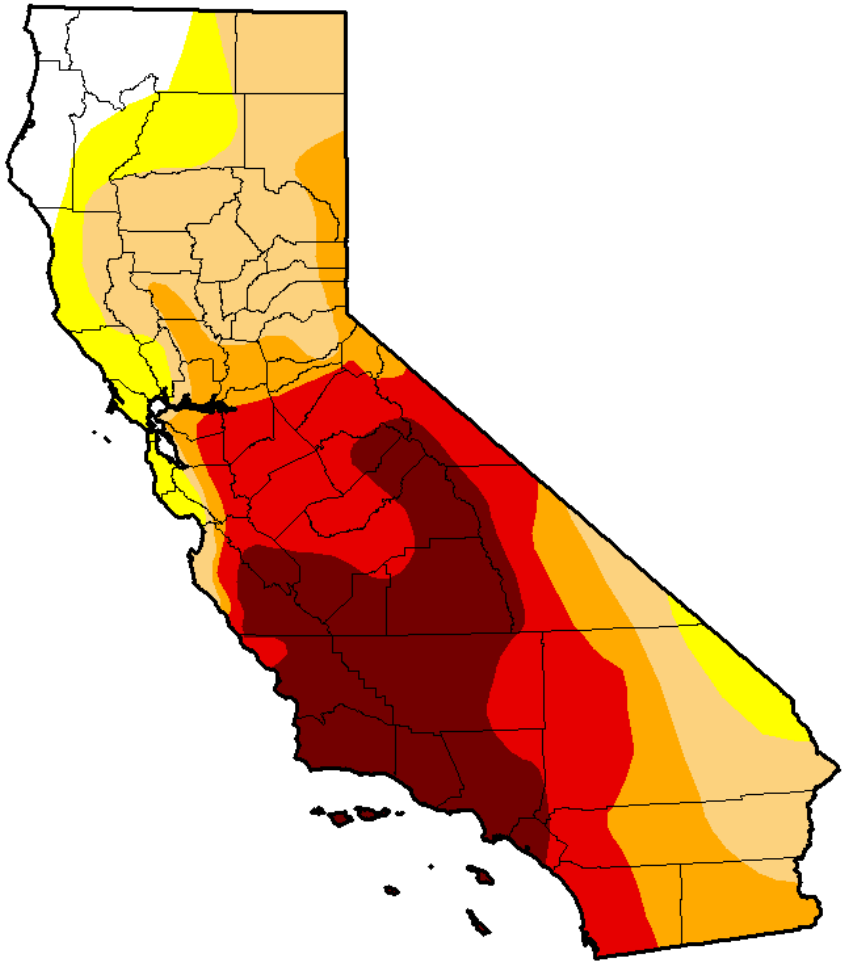
Water Reuse

- CA *Title 22*
  - Recycled water used for the surface irrigation of: Food crops, Parks and playgrounds, School yards, Residential landscaping, golf courses
- Disinfected tertiary recycled water
  - Conventional “oxidation” and “coagulation”
  - Filtration
  - Disinfection
    - < 2.2 MPN/100 mL total coliforms
    - 5 $\log_{10}$ virus removal or inactivation
    - CT > 450 mg·min/L

From: http://www.tpomag.com/editorial/2013/06/odor_control_and_disinfection4

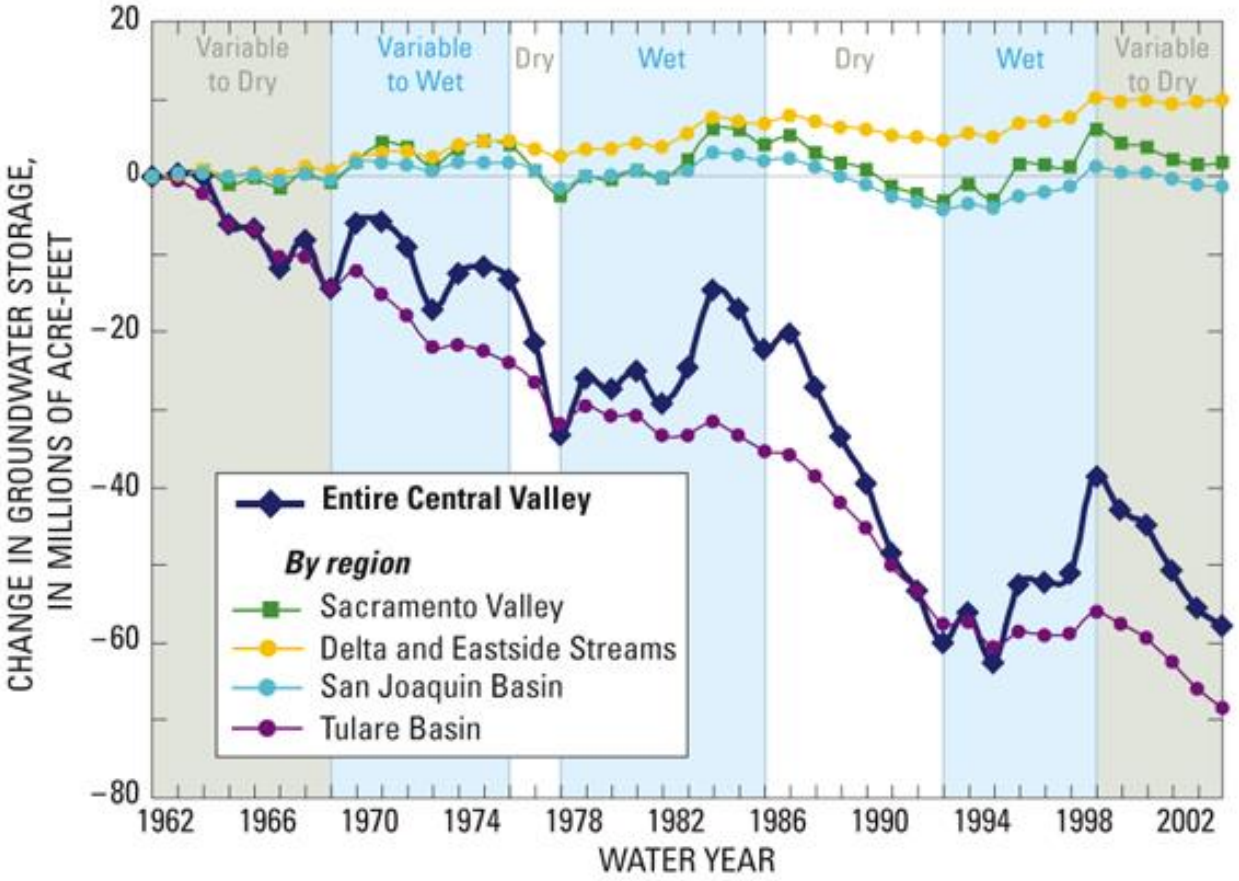
CA Water Shortages and Agriculture

- CA and many other western states have experienced severe drought recently
- Groundwater depletion in CA has reached a critical stage
- CA (Central Valley) produces majority of fruits and vegetables in U.S.
- Current agricultural practices in agricultural California are unsustainable

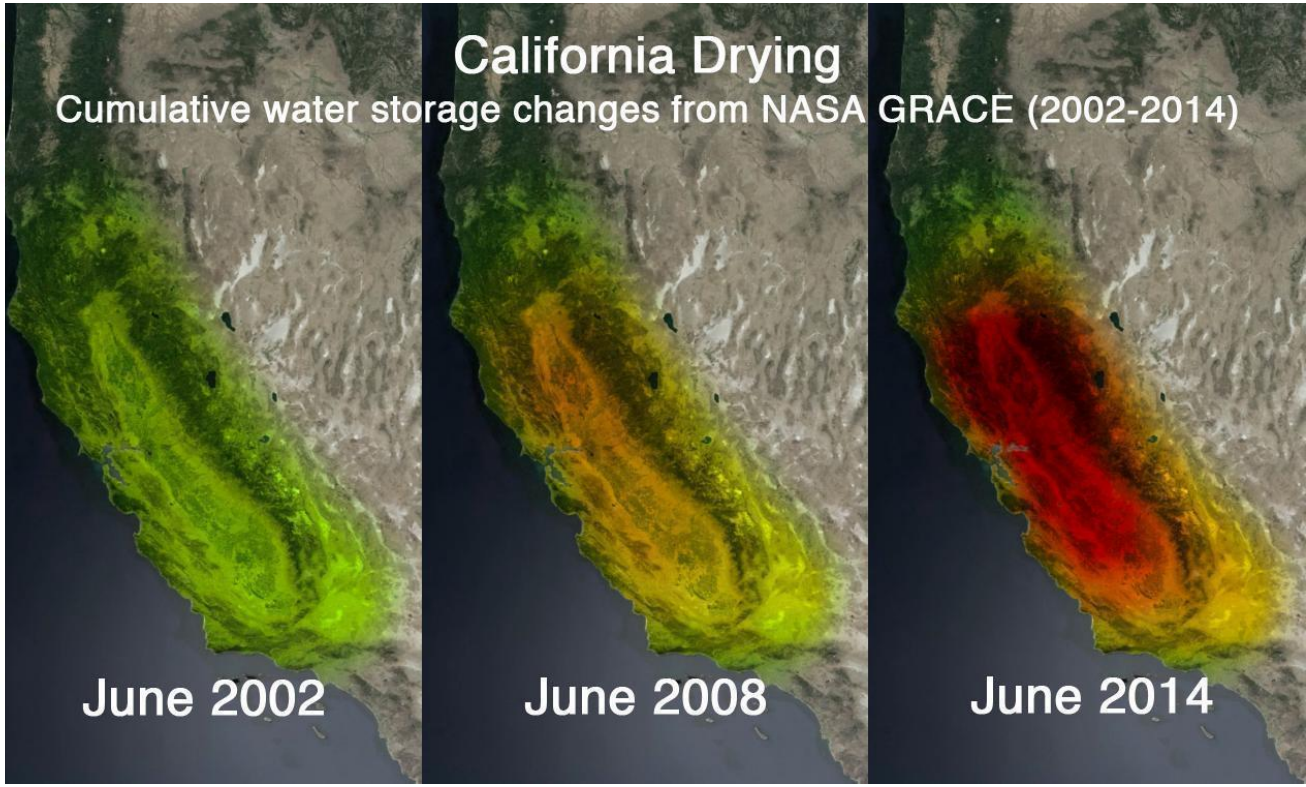


From: http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?CA

CA Water Shortages and Agriculture



From: http://beer-runner.blogspot.com/2014/06/californias-drought-hasnt-affected-its.html



From: http://www.latimes.com/science/sciencenow/la-sci-sn-california-drought-groundwater-satellite-20141002-story.html

Proposal: Year-Round Production of Fruits, Vegetables in Temperate Climates

- Thermal energy from effluent
- Nutrients from effluent
- Water from effluent
- Primary impact: Economically-depressed areas
  - Concept of a “Food Desert”
  - Method of providing fresh fruit and vegetables in depressed areas, year-round

Summary and Conclusions

- Wastewater represents a largely-untapped resource
  - Nutrients
  - Water
  - Energy
- Opportunities exist to harvest these resources
- WWTPs are among largest consumers of electrical power
  - Opportunities exist to develop power-neutral or power-positive facilities
  - Opportunities exist to harvest other resources
- Changes will require technical, cultural changes
- Future work will be at the intersection of engineering and social sciences

Thank You!

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